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The Physiological Effects of a Season of Varsity Swimming Competition and Training on Selected Bodily Responses of Swimmers

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THE PHYSIOLOGICAL EFFECTS OF A SEASON OF VARSITY SWIMMING COMPETITION AND TRAINING ON SELECTED BODILY RESPONSES OF SWIMMERS

BY

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This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Adviser Date

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CHAPTER I

INTRODUCTION

Significance of the Study

Success in any athletic endeavor depends upon many interrelated factors including physiological aspects, mechanical, and psychological principles. Although in recent years reported literature concerning these factors has been sizeable, much still remains to be researched.

Swimming's therapeutic and recreational values have long been known and enjoyed, but competitive swimming and most swimming records date only from 1870.[1] The techniques for coaching swimming have been borrowed or assimilated from other sports, mainly track and field. For improving physiological condition many track and field techniques have also been borrowed by swimming coaches and applied to swimming. The effects of swimming on physiological measurements have not been extensively researched; however, some research on swimming has been completed in recent years. Faulkner states, ". . . the only comprehensive physiological investigations of swimming have been of channel swimmers and Swedish girl swimmers."[2] Accordingly, an investigation of the effects of a season of competitive swimming on certain physiological bodily responses was deemed necessary by the investigator.

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[1] John A. Faulkner, What Research Tells The Coach About Swimming, ed. John M. Cooper (Washington: American Association for Health, Physical Education, and Recreation, 1967), p. v.

[2] Ibid., p. 7.

Statement of the Problem

The purpose of this investigation was to study the physiological effects of a season of varsity swimming competition and training on selected bodily responses of swimmers.

Hypothesis

The following hypothesis was investigated: Throughout the competitive swimming and training season, there is no significant trend that can be observed in the selected bodily responses of the varsity swimmers.

Limitations and Delimitations

1. The eight male subjects for this study were chosen from members of the South Dakota State University varsity swimming team on the basis of individual participation during the previous season and on predicted participation in varsity competition.

2. Only these physiological parameters were measured: weight, maximal oxygen uptake, forced vital capacity, forced expiratory volume for one second, muscular endurance of the shoulder girdle, leg power, body fat, ventilation equivalence for oxygen, and maximal pulmonary ventilation.

3. The University, at this time, does not have a swimming pool. Therefore, the swimming team used the local high school pool.

4. The scheduling of practice times for the use of the pool was undesirable in that plans for the high school and city swimming programs were made before the University team schedule was considered.

5. The subjects were tested before the season began and every five weeks thereafter until the investigation was completed.

Definition of Terms

Maximal Oxygen Uptake (Maximal $\dot{V}_{O_2}$). Maximal $\dot{V}_{O_2}$ is the maximum amount of oxygen that can be supplied to the active tissues of the body per minute. This measurement may be recorded in liters per minute (l/min) or milliliters per kilogram of body weight per minute (ml/kg/min). This term is also known as aerobic capacity, maximum oxygen intake, or maximum oxygen consumption.[3]

Forced Vital Capacity (FVC). The FVC ". . . is the maximum volume of air that can be rapidly and forcibly expired from the lungs following a maximum inspiration."[4] This measurement is usually expressed in liters of air.

Forced Expiratory Volume for One Second ($FEV_{1.0}$). The $FEV_{1.0}$ is ". . . the volume of air expired during the first second of the forced vital capacity test."[5] This measurement is usually expressed in liters of air.

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[3]Paul Brynteson, "The Effects of Training Frequencies on the Retention of Cardiovascular Fitness" (unpublished Doctor's dissertation, Springfield College, 1969), p. 8.

[4]Frank C. Consolazio, Robert Johnson, and Louis Pecora, *Physiological Measurements of Metabolic Functions in Man* (New York: McGraw-Hill Book Company, Inc., 1963), p. 221.

[5]Ibid., p. 223.

Muscular Endurance. Muscular endurance is ". . . the ability of a muscle or muscle group to maintain a sub-maximal contraction over a period of time."[6] In this study the muscular endurance of the arms and shoulder girdle was measured.

Power. Power is the ". . . capacity of the individual to bring into play maximum muscle contraction at the fastest rate of speed."[7] In this study the power of the legs was measured.

Percent Body Fat. Body fat is the weight in pounds of an individual's body tissue that is in excess of lean body weight. In this study, body fat was expressed as a percentage of the subject's total body weight.

Ventilation Equivalence for Oxygen ($\dot{V}E_{O_2}$). The $\dot{V}E_{O_2}$ is the quantity of inspired air required for each one hundred cubic centimeters of oxygen consumed per minute. It is an indication of the efficiency of ventilation.[8]

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[6]Carl E. Willgoose, Evaluation in Health Education and Physical Education (Philadelphia: Lea & Febiger, 1964), p. 105.

[7]Harold M. Barrow and Rosemary McGee, A Practical Approach to Measurement in Physical Education (Philadelphia: Lea & Febiger, 1964), p. 116.

[8]Benjamin Ricci, Physiological Basis of Human Performance (Philadelphia: Lea & Febiger, 1967), pp. 252-253.

Maximal Pulmonary Ventilation (Maximal $\dot{V}_E$). Maximal $\dot{V}_E$ ". . . is the maximal volume of air that a subject can move into and out of the lungs as a physiological response to exercise."[9] The maximal $\dot{V}_E$ was measured during the expiratory phase and was expressed as liters of air per minute.

[9]Brynteson, op. cit., p. 10.

CHAPTER II

REVIEW OF THE RELATED LITERATURE

The review of related literature was divided into three parts: (1) literature concerning maximal oxygen uptake; (2) literature related to the effects of training on specific pulmonary parameters; and (3) literature related to muscular endurance, leg power, and percent body fat.

The purpose of these reviews was to provide knowledge of techniques and methods that have been used in similar studies. The review also provided information about the design and execution of the study. It also was an aid in the analysis and interpretation of results.

Literature Related to Maximal $\dot{V}_{O_2}$ as a Measure of Cardiovascular and Respiratory Efficiency

During any type of activity by which a person is forced to do bodily work, that person's metabolism will increase. The metabolic increase is the result of the action of the body's muscles. During work, the muscles of the body must receive oxygen and consequently dispose of carbon dioxide. With more exercise, the muscles need additional oxygen. To compensate for this increase of oxygen, the respiratory and cardiovascular systems make adjustments by increasing their activity. In this way, the necessary oxygen is made available to the muscle groups.[1]

After extensive work the respiratory and cardiovascular systems cannot make any further adjustments to the increasing work load. The maximal amount of oxygen that can be supplied and utilized by the muscle tissue is reached at this point. This maximal amount of oxygen can be measured and is termed the maximal oxygen uptake or aerobic capacity. Most physiologists use this measure as an indication of man's physical fitness and his capacity or ability to perform and sustain long-term work of high intensity.[2, 3, 4, 5]

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[1]Thomas F. Morrison, Fredrick D. Cornett, and Edward Tether, Human Physiology, (New York: Holt, Rinehart, and Winston, Inc., 1959), p. 69.

[2]Laurence E. Morehouse and Augustus T. Miller, Physiology of Exercise (fourth edition; St. Louis: The C. V. Mosby Company, 1963), p. 258.

[3]Peter V. Karpovich, Physiology of Muscular Activity (sixth edition; Philadelphia: W. B. Saunders Company, 1965), p. 110.

[4]Donald K. Mathews, et al., Physiology of Muscular Activity and Exercise (New York: The Ronald Press Company, 1964), p. 324.

[5]John A. Faulkner, What Research Tells The Coach About Swimming, ed. John M. Cooper (Washington: American Association for Health, Physical Education, and Recreation, 1967), p. 12.

Astrand and Ryhming believe that tests involving large muscle groups must be selected to measure cardiorespiratory fitness. The capacity of the individual to continue heavy prolonged muscular work depends upon the supply of oxygen to the working muscles. When large muscle groups engage in any type of work, the factor that seems to limit maximal oxygen intake is the capacity and regulation of the oxygen transporting system. The fitness of the respiratory system thus becomes a critical factor when considering maximal oxygen intake.[6]

One way of increasing respiratory efficiency is through training. If training increases respiratory efficiency, training will also affect the maximal oxygen uptake. Knehr and his associates found a 7 percent increase in the maximal oxygen intake for 14 men who were studied over a period of 6 months and were in a process of physical training.[7] An untrained man can have a maximal oxygen uptake of about 2 liters per minute and an athlete or trained person can have an oxygen uptake of 4 liters or more.[8] Robinson and Harmon studied 9 non-athletic

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[6] P. O. Astrand and Irma Ryhming, "A Nomogram for Calculation of Aerobic Capacity from Pulse Rate During Submaximal Work," Journal of Applied Physiology, 7:218-221, September, 1954.

[7] C. A. Knehr, D. B. Dill and W. Neufeld, "Training and Its Effects on Man at Rest and at Work," American Journal of Physiology, 136:148-156, March 1942.

[8] Karpovich, op. cit., p. 56.

individuals and found an 18-percent increase in maximal oxygen intake at the conclusion of a training period.[9] Differences in maximal oxygen intake between world-class endurance athletes and non-athletic individuals were reported by Astrand. The world-class athletes had the ability to consume large quantities of oxygen per kilogram of body weight. This would indicate that maximal oxygen intake is an important factor when endurance is considered.[10]

Welch _et al._ have found statistically significant relationships between body weight and maximal oxygen intake.[11] Buskirk and Taylor report similar results.[12] Astrand notes that on the bicycle ergometer the same work load is usually placed upon all subjects exclusive of body weight but that the work load when running on the treadmill will vary for each subject depending upon body weight. Maximal oxygen uptake can be more validly expressed in milliliters per kilogram of body weight.[13]

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[9] S. Robinson and P. M. Harmon, "The Effects of Training and of Gelatin upon Certain Factors which Limit Muscular Work," _American Journal of Physiology_, 133:161-169, May, 1941.

[10] P. O. Astrand, "Human Physical Fitness with Special Reference to Sex and Age," _Physiological Reviews_, 36:307-335, July, 1956.

[11] B. E. Welch, P. Riendeau, C. E. Crisp and R. S. Isenstein, "Relationships of Maximal Oxygen Consumption to Various Components of Body Composition," _Journal of Applied Physiology_, 12:395-398, May, 1958.

[12] E. Buskirk and H. L. Taylor, "Maximal Oxygen Intake and Its Relation to Body Composition with Special Reference to Chronic Physical Activity and Obesity," _Journal of Applied Physiology_, 11:72-78, July, 1957.

[13] Astrand, loc. cit.

Slonim, Gillespie, and Harold used 50 naval aviation cadets between the ages of 18 and 25 years to calculate maximal oxygen uptake. All subjects, when tested, warmed up on a treadmill which ran at a speed of 3.5 mph at a 10-percent grade for 6 minutes. After initial testing at various treadmill grades, each subject was tested at a particular grade which he could maintain and complete the test. Expired gas was collected during the sixth minute of exercise. The mean for oxygen uptake was 4.05 ± 0.39 liters per minute. The range was 3.22 liters per minute to 5.17 liters per minute.[14]

Buskirk and Taylor determined the maximal oxygen intake of 46 male college students and 13 soldiers. The students warmed up on a treadmill which was moving at 3 mph on a 5-percent grade for 15 minutes. The soldiers warmed up for 10 minutes at 3.5 mph on a 10-percent grade. At the conclusion of each warm-up all subjects ran for 3 minutes on a grade which suited his capacity and at a speed of 7 mph. The mean maximal oxygen intake for 54 students and soldiers was found to be $3.59 \pm .51$ liters per minute. It was concluded that maximal oxygen intake, when used to establish a person's fitness for exhausting work, should be expressed in liters or milliliters per kilogram of body weight.[15]

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[14]N. B. Slonim, D. G. Gillespie and W. H. Harold, "Peak Oxygen Uptake of Healthy Young Men as Determined by a Treadmill Method," Journal of Applied Physiology, 10:401-404, May, 1957.

[15]Buskirk and Taylor, loc. cit.

Wilmore studied the relationship between maximal oxygen uptake and endurance capacity. Thirty non-athletes were used as subjects, and each rode a bicycle ergometer until exhaustion was achieved. The subjects took the maximal oxygen uptake test twice and a correlation of .86 was found between them. A correlation of .84 was found between maximal oxygen uptake (1/min) and endurance capacity. Correlations of this magnitude seem to substantiate the validity and reliability of the maximal oxygen uptake test as a measure of performance capacity and physical fitness.[16]

Magel and Faulkner evaluated the maximal oxygen uptakes of college swimmers running on a treadmill, swimming free, and tethered swimming. Twenty-six swimmers were given the various tests. Seventeen swimmers were tested on the treadmill and the tethered swimming tests. Fifteen swimmers were used in the comparison of the tethered swimming test and the free swimming test. The treadmill test consisted of runs of 5 minutes at 7 mph with a 10-minute rest between each run. The test began at 0 grade and increased by increments of 2.5-percent in grade until maximum voluntary physical work capacity was attained. In the tethered swimming test, the swimmers were attached to a pulley-weight system and maintained a stationary position over a fixed object on the bottom of the pool. The test consisted of a 3-minute swim

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[16]Jack C. Wilmore, "Maximal Oxygen Intake and Its Relationship to Endurance Capacity on the Bicycle Ergometer," Research Quarterly, 40:203-210, March, 1969.

starting at a work load of 4.55 kg. Each swimmer then rested 3 to 5 minutes before beginning again. The work level was increased by 1.14 kg until the swimmer could no longer support the weight and remain above the fixed object. The free swimming test consisted of ten 50-yard sprints spaced at intervals of 45 to 60 seconds. After a warm-up the swimmer had his nose clipped shut and was outfitted with a headpiece and breathing valve. Six 50-yard sprints were then performed with a 10-second rest interval between each swim. Gas was collected in neoprene bags by a technician walking alongside the swimmer carrying a rod attached to the bags. Gas samples from all 3 tests were analyzed for carbon dioxide, oxygen, and nitrogen with a model number 29 Fisher-Hamilton gas partitioner. The maximal oxygen untake during the test-retest tethered swimming was found to be 55 ml/kg/min $\pm$ 3.7; on the free test it was 55 ml/kg/min $\pm$ 3.5.[17]

The Fitness Research Unit of the University of Alberta investigated intercollegiate athletics and maximal oxygen comsumption. Six swimmers from the university were tested twice, once before and once after the season. Each swimmer was tested on a treadmill at 6 mph for 2.5 minutes on 0 grades. A 10-minute rest was followed by a retest at a 2.5-percent increase in grade. This procedure was repeated until each

[17] John R. Magel and John A. Faulkner, "Maximum Oxygen Uptakes of College Swimmers," Journal of Applied Physiology, 22:929-938, May, 1967.

subject could do no further work. Gas samples were collected the last 30 seconds of each 2.5 working minute. The investigators found that before the season began the swimmers had a mean maximal consumption of 54.79 ml/kg/min ± 4.47; the mean at the end of the season was 53.40 ml/kg/min ± 3.66. This decrease was not statistically significant.[18]

Magel and Andersen investigated the pulmonary diffusing capacity and cardiac output in young trained and untrained Norwegian swimmers. Ten well-trained male swimmers were measured on a bicycle ergometer for maximal $\dot{V}_{O_2}$. Each subject began at a work load of 300 kgm/min; the load was increased by 300 kgm each minute until exhaustion ensued. The 10 subjects pedaled at a rate of 50 rpm. Most work periods lasted approximately 8 minutes and maximal $\dot{V}_{O_2}$ was measured by open-circuit spirometry and was established when the $\dot{V}_{O_2}$ plateaued or any two maximum measurements agreed within 5 percent of each other. The mean oxygen uptakes of the trained Norwegian swimmers were found to be 58.5 ml/kg/min ± 3.8 on the bicycle ergometer.[19]

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[18] Maxwell L. Howell, et al., "Intercollegiate Athletics and Maximal Oxygen Consumption" (unpublished report, University of Alberta, Edmonton, Alberta, Canada), pp. 1-38.

[19] John R. Magel and Lange Andersen, "Pulmonary Diffusing Capacity and Cardiac Output in Young Trained Norwegian Swimmers and Untrained Subjects," Medicine and Science in Sports, 1:131-139, September, 1969.

Faulkner states that highly trained college swimmers average 56 ml/kg/min with a range of 50 to 70 ml/kg/min as compared to distance runners who average 66 ml/kg/min with a range of 60 to 80 ml/kg/min.[20]

Hermansen and Andersen compared the maximal oxygen uptake of young male and female athletes and non-athletes. Fourteen well-trained male athletes had an average maximal $\dot{V}_{O_2}$ of 71 ml/kg/min compared to 44 ml/kg/min for 12 non-athletic subjects. Five well-trained athletic females had an average maximal $\dot{V}_{O_2}$ of 55 ml/kg/min compared to 38 ml/kg/min in 12 non-athletic subjects.[21]

Summary

Cardiovascular and respiratory efficiency can be defined broadly as physical fitness. According to Ricci, physical fitness" . . . can be separated into two categories: capacity tests as exemplified by cardiopulmonary function, pulmonary function. . ., and motor performance tests.[22] Measurement of maximal $\dot{V}_{O_2}$ is endorsed by many investigators

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[20]Faulkner, loc. cit., p. 12.

[21]Lars Hermansen and K. Lange Andersen, "Aerobic Work Capacity in Young Norwegian Men and Women," Journal of Applied Physiology, 20:425-431, May, 1965.

[22]Benjamin Ricci, Physiological Basis of Human Performance (Philadelphia: Lea & Febiger, 1967), p. 233.

as the best measure of physical fitness.[23, 24, 25, 26, 27, 28] Attainment of physical fitness as well as the maintenance of fitness level can be accomplished through training. Endurance training in particular has been shown to improve maximal $\dot{V}_{O_2}$.[29, 30] Maximal $\dot{V}_{O_2}$ when used to establish a person's fitness should be expressed in milliliters per kilogram of body weight.[31, 32, 33, 34]

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[23]Morehouse, loc. cit.

[24]Karpovich, op. cit., p. 238.

[25]P. O. Astrand, Cardiac Output during Submaximal Work," _Journal of Applied Physiology,_ 19:268-274, March, 1964.

[26]F. W. Kasch, _et al._ "A Comparison of Maximal Oxygen Uptake by Treadmill and Step-test Procedures," _Journal of Applied Physiology,_ 21:1387-1388, July, 1966.

[27]Mathews, _et al._, loc. cit.

[28]Astrand and Rhyming, loc. cit.

[29]Knehr, Dill and Neufeld, loc. cit.

[30]Robinson and Harmon, loc. cit.

[31]Buskirk and Taylor, loc. cit.

[32]Welch, _et al._, loc. cit.

[33]Astrand, loc. cit.

[34]Slonim, Gillespie, and Harold, loc. cit.

Literature Related to the Effects of Training on Specific Pulmonary Parameters

Saltin and Astrand investigated the maximal oxygen uptake of 95 highly conditioned Swedish male athletes. The investigators found that the mean maximal oxygen uptake for the 15 males with the highest values was 5.75 liters per minute with an extreme of 6.17 liters per minute. Mean pulmonary ventilation during maximal exercise was 158.7 liters per minute with a range of 140 liters to 203 liters per minute. Pulmonary ventilation of this magnitude was considered very high and could be attributed to the athlete's highly trained condition.[35]

McArdle and Magel conducted an investigation of physical work capacity and maximal oxygen uptake in treadmill and bicycle exercise. The mean maximal oxygen uptake for 23 male college students was 38.5 ml/kg/min $\pm$ 4.3 during bicycle exercise and 42.7 ml/kg/min $\pm$ 4.9 during treadmill exercise. Maximal pulmonary ventilation (BTPS) for bicycle exercise was 121 $\pm$ 23.9 liters per minute and 127.9 $\pm$ 27.4 liters per minute for treadmill exercise.[36]

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[35] Bengt Saltin and P. O. Astrand, "Maximal Oxygen Uptake in Athletes," Journal of Applied Physiology, 23:353-358, September, 1967.

[36] William D. McArdle and John R. Magel, "Physical Work Capacity and Maximum Oxygen Uptake in Treadmill and Bicycle Exercise," Medicine and Science in Sports, 2:118-123, Fall, 1970.

In the study of 10 young trained Norwegian swimmers, Magel and Andersen found the mean maximal oxygen uptake to be 58.5 ml/kg/min ± 3.8; the mean maximal pulmonary ventilation (BTPS) was 143.8 ± 21.8 liters per minute. A mean value of 5.34 ± .45 liters was found for forced expiratory volume for one second; the mean for vital capacity was 6.37 ± .72 liters per minute. No mention was made in this study to ventilation equivalence for oxygen and forced vital capacity.[37]

Magel and Faulkner found a mean of 54.7 ml/kg/min ± 3.4 for maximal oxygen uptake and a pulmonary ventilation (STPD) mean of 112 ± 15 liters per minute during tethered swimming for college swimmers. Mean maximal oxygen uptake during free swimming was 56.3 ml/kg/min ± 3.9 and a mean pulmonary ventilation (STPD) of 114 ± 14 liters per minute.[38]

Brynteson studied the effects of different weekly exercise frequencies on the retention of cardiovascular fitness following a physical conditioning program. Twenty-one male subjects ranging in age from 20 to 38 years participated in a 5-week daily conditioning program on a bicycle ergometer. The subjects worked at an intensity level which was 80-percent of their maximum for a period of 30 minutes.

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[37] Magel and Andersen, loc. cit.

[38] Magel and Faulkner, loc. cit.

The investigator found that maximal oxygen uptake, maximal pulmonary ventilation, and forced expiratory volume for one second increased significantly, but that forced vital capacity and ventilation equivalence for oxygen did not significantly increase.[39]

Kelly studied the relationship between selected pulmonary function measurements and cardiovascular fitness when measured by a maximal oxygen test. Thirty-five male volunteers ranging in age from 20 to 30 years old were selected. Forced expiratory volume for one second, maximum pulmonary ventilation, and ventilation equivalence for oxygen were physiological parameters initially tested and then later repeated. Kelly made the following conclusions: (1) when oxygen is being consumed at maximum levels, maximum pulmonary ventilation and ventilation equivalence for oxygen are highly related to the maximal oxygen uptake; (2) forced expiratory volume for one second is the only functional pulmonary measurement that is significantly related to cardiovascular fitness and, therefore, to physical fitness.[40]

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[39] Paul Brynteson, "The Effects of Training Frequencies on the Retention of Cardiovascular Fitness" (unpublished Doctor's dissertation, Springfield College, 1969), pp. 1-155.

[40] John M. Kelly, "The Relationship between Selected Measures of Pulmonary Function and Cardiovascular Fitness" (unpublished Doctor's dissertation, Springfield College, 1969), pp. 1-173.

Summary

Pulmonary parameters, specifically maximum pulmonary ventilation, maximal oxygen uptake, and forced expiratory volume for one second can be improved through physical training.[41, 42, 43, 44] Recent investigations indicate that a significant relationship exists between specific pulmonary parameters and maximal oxygen uptake.[45]

Literature Related to Muscular Endurance, Leg Power, and Percent Body Fat

The stronger individual possesses a distinct advantage during any type of physical work, especially athletics. Strength, endurance, and power are terms which have become ambiguous and sometimes synonymus. Strength as defined by Johnson and Nelson is the "Muscular force exerted against movable and immovable objects."[46] Endurance, according to Barrow and McGee is ". . . the result of a

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[41]Saltin and Astrand, loc. cit.

[42]Magel and Andersen, loc. cit.

[43]Brynteson, loc. cit.

[44]Kelly, loc. cit.

[45]Ibid.

[46]Barry L. Johnson and Jack K. Nelson, Practical Measurements for Evaluation in Physical Education (Minneapolis: Burgess Publishing Company, 1969), p. 241.

physiological capacity of the individual to sustain movement over a period of time."[47] Johnson and Nelson state that power is ". . . the ability to release maximum force in the fastest possible time."[48]

Johnson and Nelson suggest that Hitchcock and Sargent were the earliest investigators of muscular endurance specifically of the arms and shoulders of college men and compiled extensive data on this variable.[49] The same authors state:

> Muscular endurance may be either dynamic or static in nature and concerns the ability of a muscle to repeat indentical movements or pressures, or to maintain a certain degree of tension over a period of time. Basically there are three types of muscular endurance test. . . Dynamic test of Muscular Endurance. . . Repetitive Static Tests of Muscular Endurance. . . Timed Tests of Muscular Endurance.[50]

Activities which have been included in measuring muscular endurance are chins or pull-ups, endurance dips, push-ups, sit-ups, squat jumps, flexed arm hang, squat thrusts, modified push-ups and repetitive press test with a spring scale.[51, 52]

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[47] Harold M. Barrow and Rosemary McGee, A Practical Approach to Measurement in Physical Education (Philadelphia: Lea & Febiger, 1964), p. 547.

[48] Johnson and Nelson, op. cit., p. 80

[49] Ibid., p. 10.

[50] Ibid., p. 272.

[51] Barrow and McGee, op. cit., pp. 184-268.

[52] Johnson and Nelson, op. cit., pp. 273-293.

Henry states that the Sargent Jump test, first validated by L. W. Sargent, was a test of neuromuscular efficiency involving strength, speed and coordination, and driving power. Collins and Howe, as well as Bovard and Cozens, contributed to the validity of the Sargent Jump test. Furthermore, Henry states that in 1932 McCloy experimentally validated the Sargent Jump test and stated that it was the best single test available for predicting power.[53]

Gray, Start, and Glencross studied 80 male students ranging in age from 17 to 22 years in an attempt to establish a valid test of leg power. The subjects attempted a vertical jump by taking a sideways position to a jump board, one arm behind the back, the other arm touching the head and parallel to the jump board. The head and back had to remain straight throughout the entire test. Difference in jumping height and tip-toe reaching height was recorded as well as the differences between the centers of gravity of the tip-toe reaching and squatting position and between tip-toe reaching and jump reaching height. The results were statistically significant and enabled the vertical power jump to be expressed in foot-pounds of work done per second by the subject's legs alone.[54]

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[53] Franklin Henry, "The Practice and Fatigue Effects in the Sargent Jump," Research Quarterly, 13:16-29, March, 1942.

[54] R. K. Gray, K. B. Start, and D. J. Glencross, "A Test of Leg Power," Research Quarterly, 33:44-50, March, 1962.

In a later study by Gray, Start and Glencross, the investigators attempted to modify their earlier work on the vertical power jump. Their modification consisted of a less time-consuming and more practical test of the vertical power jump. The center of gravity measurements were eliminated as were the differences between squatting and tip-toe reaching heights. The authors concluded that the modified vertical power should be used when measuring leg power because it is highly reliable (.977) and highly valid (.989) when compared to the jump reach test, standing broad jump, and the squat jump. The formula developed by the investigators to express the amount of work done in foot-pounds per second by the legs was:

$$\text{Work} = \frac{W \times H}{12}$$

W = weight of the subject in pounds.

H = difference between tip-toe reach and maximum jump reach.[55]

Fat tissue is widely distributed throughout the body and accounts for a large percentage of the total body weight. Fat tissue is found to be approximately 18-percent of the total body weight in males and 28-percent in females. Fat has three important functions in

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[55]R. K. Gray, K. B. Start, and D. J. Glencross, "A Useful Modification of the Vertical Power Jump," Research Quarterly, 33:230-235, May, 1962.

the body: (1) a reserve supply of energy, (2) a pad to absorb shock, and (3) an insulator to maintain the normal body temperature by preventing the loss of body heat.[56]

Excessive fat has generally been considered undesirable for endurance athletes. McLester and Darby believed that too much fat interfered with physical activity, reduced muscular efficiency, and interfered with movement of the diaphragm and abdominal muscles.[57]

Measurements of body fat and body density has been a fairly accurate way of predicting and establishing the physical condition of an individual throughout a season of activity. Skinfold measurements were brought to attention by Thompson, Buskirk, and Goldman in 1956. The skinfold procedure is rapid, reasonably precise, and an inexpensive method for estimating body fat. The authors studied 14 college basketball players and 10 college hockey players at the University of Minnesota. The basketball players decreased in weight at the end of their season by 2.1 pounds, and the hockey players' weight increased an average of .9 pounds. Neither measurement was statistically significant. Three subcutaneous fat measurements for

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[56]Morrison, Cornett and Tether, op. cit., p. 33.

[57]James S. McLester and William J. Darby, "Obesity and Leanness," Nutrition and Diet in Health and Disease (sixth edition, Philadelphia: W. B. Saunders Company, 1952), p. 334.

both groups were shown to be significant. These measurements were taken at the chest, abdomen, and upper arm. The basketball players lost an average of 1 millimeter in the chest region, 2.86 millimeters in the abdomen, and 3 millimeters in the upper arm. The hockey players showed fat losses of 1.91 millimeters in the chest, 1.91 millimeters in the abdomen, and 2.55 millimeters in the upper arm.[58]

Kireilis and Cureton determined body weight and made 6 skinfold measurements (hip, cheek, abdomen, front thigh, rear thigh, and gluteal) before conditioning three obese males on the treadmill for six weeks. It was found that no significant weight changes occurred but that a 20-percent decrease in skinfold measurements did occur.[59]

Thompson used three skinfold measurements (abdomen, chest, and arm) to determine changes in body fat of varsity football players. The football players were measured before and at the end of their season. The investigator found that body weight did not change significantly but that significant decreases occurred in the three skinfold

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[58]C. W. Thompson, E. R. Buskirk, and R. F. Goldman, "Changes in Body Fat Estimated from Skinfold Measurements of College Basketball and Hockey Players during a Season," Research Quarterly, 27:418-430, December, 1956.

[59]R. W. Kireilis and T. K. Cureton, "The Relationship of External Fat to Physical Education Activities and Fitness Tests," Research Quarterly, 18:123-134, May, 1947.

measurements. Body density increased with the loss of body fat. Thompson assumed that the change in body composition was a result of a conditioning program which increased muscle mass or other bodily components.[60]

Sloan states that an individual's extra weight can result from better development of bone or muscle, both of which are heavier than fatty tissue. A reliable estimate of the proportion of adipose tissue to total body weight can be derived from specific gravity or density of the body.[61]

Forsyth computed 10 regression equations to predict body density from data derived from 17 anthropometric variables. He determined that an equation using back skinfold, height, and abdominal skinfold had a reliability of .86 and a standard estimate of .005.

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[60] C. W. Thompson, "Changes in Body Fat Estimated from Skinfold Measurements of Varsity College Football Players during a Season," Research Quarterly, 30:87-93, March, 1959.

[61] A. W. Sloan, "Estimation of Body Fat in Young Men," Journal of Applied Physiology, 23:311-315, September, 1967.

$$\text{Body Density} = 1.02415 - .00169X_{15} + .00444X_1 - .00130X_{12}$$

X_{15} = diagonal skinfold at the medial border of the right scapula.

X_1 = height (decimeters).

X_{12} = abdominal skinfold midway between the umbilicus and the iliac crest.[62]

Forsyth computed the percent body fat from the body density value:

Percent Body Fat = $4.57/D_B - 4.142$.[63]

Summary

Muscular endurance of the arms and shoulder girdle can be accurately measured by endurance dips.[64, 65] The vertical power jump is a more reliable and valid measure of leg power than the Sargent Jump, squat jump, or standing broad jump.[66, 67] Body fat is an

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[62] Harry L. Forsyth, "The Estimation of Lean Body Weight in Male Athletes" (unpublished Doctor's dissertation, Springfield College, 1970), pp. 82-83.

[63] Ibid., p. 27.

[64] Johnson and Nelson, loc. cit.

[65] Barrow and McGee, loc. cit.

[66] Gray, Start, and Glencross, "A Test of Leg Power," loc. cit.

[67] Gray, Start, and Glencross, "A Useful Modification of the Vertical Power Jump," loc. cit.

accurate measurement of an individual's condition throughout a season.[68, 69, 70] Percent body fat can be determined indirectly with regression equations by using selected skinfold and anthropometric measurements.[71, 72, 73]

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[68] Thompson, Buskirk, and Goldman, loc. cit.

[69] Sloan, loc. cit.

[70] Thompson, loc. cit.

[71] Ibid.

[72] Kireilis and Cureton, loc. cit.

[73] Forsyth, loc. cit., pp. 82-83.

CHAPTER III

METHODS AND PROCEDURES

Organization of the Study

The study was completed over a twenty-five week period beginning on October 12, 1970, and ending on April 3, 1971. This period was divided into two five-week segments, two four-week segments, and one seven-week segment which included Christmas vacation. The schedule of swimming meets forced unequal lengths of testing segments. Table I indicates the testing dates.

TABLE I

TESTING DATES

Test	Date	Comments
1	Oct. 12--15	Immediately prior to the beginning of the swimming season
2	Nov. 16--20	After five weeks of preparatory swim training
3	Jan. 4--8	Just after Christmas vacation
4	Feb. 8--11	Middle of the duel meet competition phase
5	March 8--11	Immediately following the conference swimming meet
6	March 30--April 2	Four weeks following the conference meet

The conditioning program followed during the swimming season included fast interval, slow interval, repetition, Fartlek, and overdistance training. Fast interval consisted of fast repeat swims with long rest periods; slow interval consisted of repeat swims slower than race speed with a short or incomplete rest period. Repetition consisted of repeat swims faster than race speed over a short distance with long rest periods. Fartlek utilized swimming long distances and varying the speed; overdistance consisted of swimming continuously at distances longer than the actual race. Fast interval, slow interval, and repetition training utilized distances from twenty-five yards to one hundred yards. Fartlek and overdistance training methods utilized distances from one hundred fifty to two thousand yards. A brief description of the season's daily practice routine and schedule can be found in Appendix A.

Source of Data

The eight male subjects for this study were chosen from members of the South Dakota State University varsity swimming team. These subjects were chosen on the basis of individual participation during the previous season and predicted participation in varsity competition. Table II indicates the characteristics of the subjects.

TABLE II

SUBJECT CHARACTERISTICS AT
THE TIME OF INITIAL TEST

Name	Age	Height	Weight	Competitive Stroke*
R.A.	19	5' 10"	157	Butterfly
J.A.	19	6' 1/4"	186	Backstroke
B.E.	18	5' 10 1/4"	161	Breaststroke
S.G.	18	5' 5"	131	Backstroke
J.M.	19	5' 10 3/4"	178	Freestyle
R.M.	19	5' 8"	149	Freestyle
K.S.	22	6' 3/4"	195	Freestyle
R.T.	21	5' 9 1/4"	163	Freestyle

*Specialty

Collection of Data

Five variables were selected to determine each subject's level of cardiovascular and respiratory fitness throughout the varsity swim training season. Maximal oxygen uptake was selected as one variable because it is considered the best single measure of man's total cardiorespiratory fitness.[1, 2] Forced vital capacity and forced expiratory volume for one second were selected as variables to measure functional pulmonary capacity.[3] Maximal pulmonary ventilation and ventilation equivalence for oxygen were selected as parameters to indicate ventilation efficiency.[4]

Although most, if not all, of the muscles of the body are involved in swimming, the shoulder girdle muscles contribute most of the propulsive force. The breaststroke is the only competitive swimming stroke in which the shoulder girdle muscles do not contribute as much as the kick in forcing the body through the water. Counsilman studied the force of the arm pull as compared to the force of the kick

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[1] Peter V. Karpovich, Physiology of Muscular Activity, (sixth edition, Philadelphia: W. B. Saunders Company, 1965), p. 110.

[2] Laurence E. Morehouse and Augustus T. Miller, Physiology of Exercise (fourth edition, St. Louis: The C. V. Mosby Company, 1963), p. 258.

[3] Frank C. Consolazio, Robert Johnson, and Louis Pecora, Physiological Measurement of Metabolic Functions in Man (New York McGraw-Hill Book Company, Inc., 1963), p. 248.

[4] John M. Kelly, "The Relationship between Selected Measured of Pulmonary Function and Cardiovascular Fitness" (unpublished Doctor's dissertation, Springfield College, 1969), pp. 1-173.

in the crawl stroke. He indicates ". . . that at fast speeds the kick contributes nothing to the propulsion created by the arms."[5] Muscle endurance of the arms and shoulder girdle as well as leg power were measured to determine whether there was any significant change during a season of competitive swimming and training in these parameters.

Measurement of Maximal Oxygen Uptake. As the amount of work increases, the amount of oxygen consumed will also increase in a linear fashion. When the work rate reaches an exhaustive high for the subject, the oxygen consumption does not increase to any extent and the subject's maximal oxygen uptake has been reached.[6, 7]

The technique that was employed in the present study to measure maximal $\dot{V}_{O_2}$ was a modification of the technique described by Dill.[8] A Monarch bicycle ergometer was used to provide the load resistance. The subject began exercising at 0.0 kg load for the first minute. The

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[5] James E. Counsilman, The Science of Swimming (Englewood Cliffs: Prentics-Hall, Inc., 1968), p. 7.

[6] P. O. Astrand and B. Saltin, "Maximal Oxygen Uptake and Heart Rate in Various Types of Muscular Activity," Journal of Applied Physiology, 16:977-981, November, 1961.

[7] H. L. Taylor, E. Buskirk, and A. Henschel, "Maximal Oxygen Intake as an Objective Measure of Cardiorespiratory Performance," Journal of Applied Physiology, 8:73-80, July, 1955.

[8] D. B. Dill, "Assessment of Work Performance," The Journal of Sports Medicine and Physical Fitness, 6:3-8, March, 1966.

load resistance on the subject was increased .5 kg per minute thereafter until the subject could not continue to exercise because of exhaustion. The bicycle seat was adjusted high enough to allow the subject to extend his legs when in the down position. This distance from the bicycle seat to the pedals was recorded for each subject and kept constant in each testing period. Each subject pedaled to the beat of a metronome set at 120 beats per minute and equal to 60 revolutions per minute for the subject pedaling throughout the entire testing procedure.

The open circuit method was used for the collection of the expired gases. Each subject's nose was shut with a nose clamp. One outlet of a two-way modified Otis-McKerrow valve was fitted with a rubber mouthpiece which the subject held between his teeth and through which he breathed. A second outlet was connected to a low resistance plastic tube which had an inside diameter of 38 cm; the remaining outlet of the Otis-McKerrow valve was open to allow the subject to inhale atmospheric air. Expired air was directed through the modified Otis-McKerrow valve into plastic tubing, which had an attached centigrade thermometer for purposes of recording expired air temperature. The expired air was then passed through a valve into a CD4 Dry Gas Meter which measured the volume of the expired air. The expired air was directed through the gas meter only during the last thirty seconds of each exercise minute. Barometric pressure and expired gas temperature readings were recorded to correct the gas volume measurements to STPD (0^{o} centigrade temperature, 760 millimeters atmospheric pressure free of water vapor).

From the dry gas meter, the expired air passed through a mixing chamber. A small electric pump was used to draw an approximate two-liter sample of the expired air into the small rubber gas bag from the mixing chamber during the last thirty seconds of the exercise minute. A Godart Pulmo-Analysor was used to analyze the percentage of CO_2 and O_2 in the expired air. This measurement was accomplished by connecting the small gas collection bags to the Pulmo-Analysor.

It was assumed that the maximal oxygen uptake was reached during exercise when the respiratory quotient was more than 1.0 and the oxygen uptake for two successive work loads was less than 150 milliliters per minute. If these indicators were not shown by the data, the subjects were retested.

Measurement of Forced Vital Capacity and Forced Expiratory Volume for One Second. The forced vital capacity (FVC) and forced expiratory volume for one second ($FEV_{1.0}$) were measured by a 13½ liter Collins Respirometer. The correction factor for the Collins Respirometer is 41.27 cc which means that every millimeter of descent of the kymograph pin equals a volume of 41.27 cc of the subject's expired air in the respirometer. After the subject had taken three maximum inspiratory breaths, he held his nose and made an expiration of the third breath as rapidly and forcibly as possible into a low resistance plastic tube which led to the respirometer with the attached kymograph. The subjects were given three trials; the first trial acquainted each subject with the procedure; the last two trials were the test. The mean of the last two trials was used to measure the FVC and $FEV_{1.0}$. The $FEV_{1.0}$ was measured as the amount of expired air that was expired in the first second of the FVC test. The FVC and $FEV_{1.0}$ were converted to body temperature, pressure, saturated units for all subjects. In a pilot study the reliability between trials two and three was found to be .95 to $FEV_{1.0}$ and .95 for FVC.

Measurement of Maximal Pulmonary Ventilation. Maximal pulmonary ventilation was measured during the maximal oxygen uptake test. It was the largest quantity of air expired during any given minute of the exercise. The gas volumes were corrected to body temperature, pressure, saturated units for all subjects.

Measurement of Ventilation Equivalence for Oxygen. Ventilation equivalence for oxygen indicates the efficiency of the diffusion of oxygen from the lungs to the blood stream. It was determined from the maximal oxygen uptake value and the maximal pulmonary ventilation value. The formula used for determining ventilation equivalence for oxygen was:[9]

$$\dot{V}E_{O_2} = \frac{\text{Maximal Ventilation (liters/min STPD)} \times 100}{\text{Maximum } \dot{V}_{O_2}}$$

Measurement of Muscle Endurance. Muscle endurance of the arms and shoulder girdle was measured. An endurance dip test was used because of the simplicity of administration, validity, and reliability of the test.[10]

The apparatus used was a set of parallel bars raised to a height so that all subjects were completely supported above the ground in the extended arm position. Each subject assumed an extended arm support between the bars and lowered himself until the elbows formed a right angle. The tester's hand was extended upward inside the bar to indicate when the subject reached a right angle. The subject then raised himself to an extended arm support and repeated the exercise

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[9] Benjamin Ricci, Physiological Basis of Human Performance (Philadelphia: Lea & Febiger, 1967), p. 252.

[10] Barry L. Johnson and Jack K. Nelson, Practical Measurements for Evaluation in Physical Education (Minneapolis: Burgess Publishing Company, 1969), p. 288.

as many times as possible. The subjects could not rest during the exercise and had to refrain from kicking and swinging in returning to a straight arm position.[11]

Measurement of Leg Power. Power, in this study, refers to muscle power of the legs. It was measured to determine any significant change during the season of swimming and training. The vertical power jump was used in measuring leg power. The equipment utilized was a jump board marked in half inches, chalk dust, and a balance beam weight scale. Each subject was weighed and then assumed a standing position facing side-ways to the jump board. One hand was behind the back touching the top of the gym shorts; the other hand and fingers were extended upward vertically facing outward. The subject stood as high as possible on his toes and touched the jump board with the middle finger. This height was measured and recorded as the reaching height. Chalk dust was applied to the subject's middle finger; he squatted down, keeping his head and back straight, jumped vertically as high as possible, and touched the jump board with the chalked middle finger. Each subject was allowed three trials; the greatest height was recorded. The difference between the reaching height and the jumping height was converted to foot-pounds by multiplying the distance by the subject's body weight and dividing by twelve.[12]

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[11] Ibid.

[12] Ibid., p. 91.

Measurement of Percent Body Fat. Percent body fat was measured according to a procedure developed by Forsyth. Forsyth measured body density of 50 male college athletes by the underwater-weighing technique. He also obtained 17 anthropometric measurements on each subject, using a combination of skeletal diameters and skinfold measurements. Ten regression equations were developed from 6 different combinations of the raw data obtained from the 50 subjects. For the present study, the equation which exhibited a combination of a multiple R (.86) and a standard error of estimate (.005) was adopted.[13]

$$\text{Body Density} = 1.02415 - .00169X_{15} + .00444X_{1} - .00130X_{12}$$

X_{15} = diagonal skinfold at the medial border of the right scapula.

X_{1} = height (decimeters)

X_{12} = abdominal skinfold midway between the umbilicus and the iliac crest.

All skinfold measurements were taken on the right side of the body with a Lange Skinfold Caliper. The subject's skin was grasped firmly by the thumb and forefinger of the investigator's left hand.

[13]Harry L. Forsyth, "The Estimation of Lean Body Weight in Male Athletes" (unpublished Doctor's dissertation, Springfield College, 1970), pp. 82-83.

The calipers were placed as close as possible to the crest of the fold. The subject's skin was lifted one centimeter from the location of the actual measuring site. Three measurements were taken at the back and abdominal skinfold sites; the mean of the three measurements at each location was used as data. The following equation was used to convert body density to percent body fat:[14]

$$\text{Percent Body Fat} = 4.57/D_B - 4.412$$

Procedure for Collecting Data

All testing was completed in the Human Performance Laboratory located in the South Dakota State University Gymnasium. The investigator employed the following procedure to acquaint the subjects with the study and tests prior to the initial testing:

1. Presentation of a general overview of the study followed by questions and answers.
2. Explanation and demonstration of the techniques for the various tests.
3. Operation of the bicycle ergometer by each subject.

Test dates and times were then set for each subject prior to each test. The subjects were asked not to participate in any strenuous

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[14] Ibid., p. 27.

type of activity prior to the testing. The procedure followed during each testing period was as follows:

1. The subject reported to the Human Performance Laboratory in shorts, T-shirt, and tennis shoes.
2. The subject, with shoes off, was weighed to the nearest pound.
3. A spirometry test for the measurement of FVC and $FEV_{1.0}$ was administered.
4. Percent body fat was determined with the subject's shirt off.
5. Endurance dips were performed by the subject.
6. The vertical power jump was administered.
7. Maximal oxygen uptake was determined through the use of the bicycle ergometer.

CHAPTER IV

ANALYSIS AND DISCUSSION OF RESULTS

Organization of the Data for Analysis

The purpose of this investigation was to study the physiological effects of a season of varsity swimming competition and training on selected bodily responses.

The data were organized to permit analysis of physiological changes that took place throughout the swimming season. The parameters that were measured and analyzed were body weight, percent body fat, forced expiratory volume for one second, forced vital capacity, muscular endurance of the arms and shoulder girdle, leg power, maximal oxygen uptake, maximal pulmonary ventilation, and ventilation equivalence for oxygen. All subjects were tested on all nine variables six times throughout the swimming season. The six testing dates were spaced approximately five weeks apart. Table III indicates the mean score for all variables on each specific testing date. Raw data for all variables are found in Appendix B.

A polynomial regression analysis was the primary statistical treatment which was applied to the data for Tests I, II, IV, and V.[1] The purpose of this analysis was to analyze the data to see whether

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[1] Robert Steel and James Torrie, Principles and Procedures of Statistics (New York: McGraw-Hill Book Company, Inc., 1960), pp. 332-345.

TABLE III

TABLE OF MEANS

Parameter	Test I	Test II	Test III	Test IV	Test V	Test VI
Weight (Lbs)	164.87	163.28	166.06	164.93	165.31	166.15
Percent Body Fat	11.48	12.77	10.46	11.07	11.31	11.07
$FEV_{1.0}$ (ml)	4253.32	3873.25	4363.39	4314.86	4415.56	4414.03
FVC (ml)	4510.80	3981.16	4723.95	4728.63	4803.81	4829.48
Endurance Dips	16.12	19.00	21.25	25.75	26.25	28.60
Vertical Power Jump	178.50	176.09	168.85	171.79	173.78	179.82
Maximal $\dot{V}_{O_2}$ (ml/kg/min)	60.38	60.79	58.17	65.08	61.55	61.92
Maximal $\dot{V}_E$ (L/min)	162.06	156.71	161.91	170.46	169.43	178.82
$\dot{V}E_{O_2}$ (L/100 ml)	2.83	2.78	3.01	2.84	3.04	3.03

they fit any specific curve throughout the swimming season. Tests III and VI were deleted from the polynomial regression statistics because they were not indicative of the season's training. Test III was taken immediately after Christmas vacation, during which no scheduled practices were held, and Test VI was taken three weeks after the completion of the regularly scheduled swimming season.

Analysis of variance was a second statistical treatment which was applied to each of the nine parameters on all six tests.[2] This procedure was used to provide additional statistical information in order to aid in the interpretation of results. An electronic computer was used for data analysis to facilitate speed and accuracy. In both statistical treatments the .05 level of confidence was required before the null hypothesis was rejected.

Analysis of Data

The results of the polynomial regression statistics for all variables are shown in Table IV. Only one of the variables studied fit a specific regression curve. The changes in endurance dips throughout the season fit a linear regression equation as indicated by an F ratio of 13.96. The equation is listed and plotted in Figure 1. The regression equations for the remaining eight variables were not significant.

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[2]Ibid., pp. 99-128.

TABLE IV

RESULTS OF POLYNOMIAL REGRESSION

Parameter	Polynomial Regression	Degrees of Freedom*	F Value
Weight	Linear	1/27	.0152
	Quadratic	1/27	.0269
	Cubic	1/27	.0130
	Quartic	1/27	.0004
	Pentic	----	-----
Percent Body Fat	Linear	1/27	.2786
	Quadratic	1/27	.2401
	Cubic	1/27	.4865
	Quartic	1/27	.0949
	Pentic	----	-----
$FEV_{1.0}$	Linear	1/27	1.0280
	Quadratic	1/27	1.2060
	Cubic	1/27	.5994
	Quartic	1/27	.3099
	Pentic	----	-----
FVC	Linear	1/26	2.6590
	Quadratic	1/26	1.7260
	Cubic	1/26	1.4810
	Quartic	1/26	.5781
	Pentic	1/26	.4344
Endurance Dips	Linear	1/26	13.9900**
	Quadratic	1/26	.1433
	Cubic	1/26	.0832
	Quartic	1/26	.9682
	Pentic	1/26	.0729

TABLE IV (continued)

Parameter	Polynomial Regression	Degrees of Freedom*	F Value
Vertical Power Jump	Linear	1/27	.1345
	Quadratic	1/27	.0227
	Cubic	1/27	.0107
	Quartic	1/27	.0148
	Pentic	----	-----
Maximal $\dot{V}_{O_2}$	Linear	1/27	1.1310
	Quadratic	1/27	.6088
	Cubic	1/27	1.2470
	Quartic	1/27	.1203
	Pentic	----	-----
Maximal $\dot{V}_E$	Linear	1/26	3.8310
	Quadratic	1/26	.0012
	Cubic	1/26	2.9440
	Quartic	1/26	.9981
	Pentic	1/26	.3935
$\dot{V}E_{O_2}$	Linear	1/26	2.0600
	Quadratic	1/26	1.6000
	Cubic	1/26	.3080
	Quartic	1/26	.8720
	Pentic	1/26	1.4700

*$F_{.05}(1/26) = 4.23$ $F_{.05}(1/27) = 4.21$ $F_{.05}(1/28) = 4.20$

**Significant beyond the .05 level of confidence

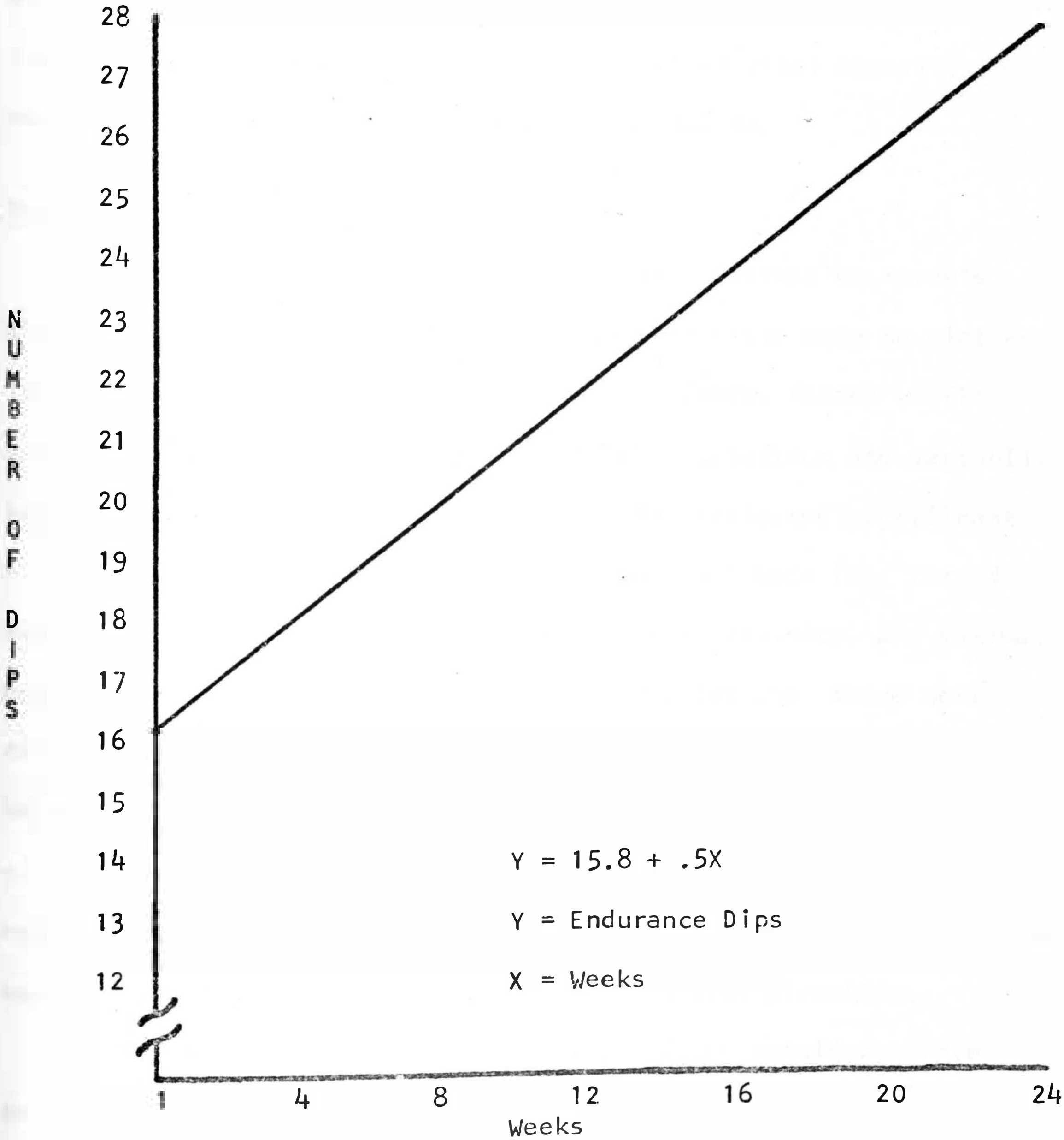

Figure 1

Linear Regression for Endurance Dips

The results of the analysis of variance for all variables are shown in Table V. Five of the nine parameters showed significance beyond the .05 level of confidence. They were percent body fat, forced expiratory volume for one second, forced vital capacity, endurance dips, and maximal pulmonary ventilation.

Summary and Discussion of Results

A summary of the polynomial regression statistics reveals that a significant linear regression equation could only be plotted for endurance dips. The remaining eight variables failed to fit a specific regression curve because of the fluctuation and variability between tests. Analysis of variance results indicated significant F ratios when applied to endurance dips, percent body fat, forced expiratory volume for one second, forced vital capacity, and maximal pulmonary ventilation. This statistic indicates that there were differences between means; however, the polynomial regression failed to show a significant trend in those differences with the exception of endurance dips. The significant F ratio for the endurance dips revealed that the data fit a linear regression equation, and that the equation was increasing in a significant positive direction.

The increase in muscular endurance of the shoulder girdle as indicated by endurance dips may be attributed to the fact that in swimming the arms and shoulder girdle muscles provide most, if not

TABLE V

ANALYSIS OF VARIANCE FOR ALL VARIABLES

Parameters	Source of Variance	Degrees of Freedom	Mean Square	F Ratio*
Body Weight (Lbs)	Subject	7	1969.45	
	Time	5	8.39	1.400
	Error	35	5.98	
Percent Body Fat (%)	Subject	7	69.87	
	Time	5	4.78	3.320
	Error	35	1.44	
$FEV_{1.0}$ (ml)	Subject	7	2572468.10	
	Time	5	336572.58	10.560
	Error	35	31877.34	
FVC (ml)	Subject	7	2851653.60	
	Time	5	827076.20	14.710
	Error	35	56219.97	
Endurance Dips	Subject	7	233.38	
	Time	5	185.48	36.100
	Error	35	5.13	
Vertical Power Jump (ft. lbs.)	Subject	7	5610.54	
	Time	5	136.92	.855
	Error	35	160.21	

TABLE V (continued)

Parameters	Source of Variance	Degrees of Freedom	Mean Square	F Ratio*
Maximal $\dot{V}_{O_2}$ (ml/kg/min)	Subject	7	109.54	
	Time	5	40.98	2.090
	Error	35	19.54	
Maximal $\dot{V}_E$ (L/min)	Subject	7	668.80	
	Time	5	688.51	2.950
	Error	35	226.85	
$\dot{V}E_{O_2}$ (L/100 ml)	Subject	7	.268	
	Time	5	.106	1.200
	Error	35	.088	

$*F_{.05}(5/35) = 2.53$

all, of the propulsive force required to move the body through the water. During each practice session an overload of the arms and shoulder girdle was stressed by having the swimmers complete lengths of the pool in a specified period of time, using their arms only. When the whole stroke was used, the swimmers were compelled to overload their arms and shoulder girdle to meet and maintain a specified time for each lap. Councilman states that "the arm stroke is the main source of propulsion and, in the case of most swimmers, the only source of propulsion."[3]

No particular trend was found for percent body fat since the regression equations were not significant. On the other hand, analysis of variance for Test I through VI showed significance at the .05 level of confidence indicating variability between means. Thompson indicated a non-significant loss of body fat in a study of football players.[4] In a similar study of basketball players and hockey players, percent body fat was decreased, but not significantly.[5] The results of

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[3] James E. Councilman, The Science of Swimming (Englewood Cliffs: Prentice-Hall, Inc., 1968), p. 25.

[4] C. W. Thompson, "Changes in Body Fat, Estimated from Skinfold Measurements of Varsity College Football Players," Research Quarterly, 30:87-90, March, 1959.

[5] C. W. Thompson, E. R. Buskirk and R. F. Goldman, "Changes in Body Fat, Estimated from Skinfold Measurements of College Basketball and Hockey Players during a Season," Research Quarterly, 27:418-430, December, 1956.

the present study are in agreement with the above. The insignificant loss of body fat may be attributed to the low initial mean percent body fat (11.48 percent). The average reported percent body fat for a general male college population is 14.69 percent.[6]

No particular trend was found for forced expiratory volume for one second and forced vital capacity because the regression equations were not significant. On the other hand, analysis of variance for Test I through VI showed significance at the .05 level of confidence, indicating variability between means. A possible reason for the significant F ratio was the low value found in Test II. All the other tests showed relatively little change from test to test.

The highest group mean in the present study for forced expiratory volume for one second was 4415.56 ml, which compares favorably to the highest group mean of 4453.00 ml in Brynteson's study and 4619.00 ml for group VI in Swisher's study.[7, 8] Although Brynteson found a significant increase for forced expiratory volume for one second upon completion of a submaximal training program,

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[6] Jack H. Wilmore and Albert R. Behnke, "An Anthropometric Estimation of Body Density and Lean Body Weight in Young Men," Journal of Applied Physiology, 27:25-31, July, 1969.

[7] Paul Brynteson, "The Effect of Training Frequencies on the Retention of Cardiovascular Fitness" (unpublished Doctor's dissertation, Springfield College, 1969), pp. 1-155.

[8] Joel Austin Swisher, "The Effects of Selected Training Intensities and Duration on Improvement and Maintenance of Cardio-respiratory Fitness" (unpublished Master's thesis, South Dakota State University, 1970), pp. 1-90.

Swisher found no increase. Brynteson's sample consisted of adult males, whereas the Swisher study and the present study dealt with college students. It may be that this parameter is not influenced by training in younger populations.

Polynomial regression and analysis of variance applied to leg power indicated no significant differences among the means, and a specific regression curve could not be plotted. The vertical power jump is a measure of explosive power of the legs and was used to measure the changes in leg power throughout a season of competitive swimming and training. The results showed no significant differences in leg power from the start to the completion of the season. Swimming is primarily an endurance event requiring long periods of muscular exercise rather than maximum muscular contraction in the shortest possible time. Although the leg power means decreased at the early part of the season and then gradually increased, polynomial regression and analysis of variance indicate that the power of the legs was neither increased or decreased significantly as a result of competitive swimming and training throughout a season. Councilman notes that the kick serves primarily as a stabilizer or neutralizer and streamliner for the body while swimming the crawl, butterfly, and backstroke. He also mentions that conditioning of the legs is important because if they are not conditioned properly, they will tend to fatigue and become less effective in the neutralizing role causing unwanted resistance.[9] In the present study, the legs may have been in good condition at the onset of the season and possibly were not influenced by conditioning. On the other hand, more time might have been spent during the practice sessions on strengthening the legs.

At the time of the initial test the subjects maximal oxygen uptake was 60.38 ml/kg/min. Howell studied the effects of participation in various athletic training programs on the maximal oxygen uptake. He reported that the swimming team's maximal oxygen uptake dropped insignificantly from 54.79 to 53.60 ml/kg/min, that the football team rose insignificantly from 51.11 to 54.90 ml/kg/min, and that the hockey team experienced a significant gain from 52.07 to 56.93 ml/kg/min from the beginning to the end of the season.[10]

Brynteson found a mean maximal oxygen uptake of 59.95 ml/kg/min for 10 football players at Springfield College immediately following the end of the competitive season.[11] Swisher found an initial group mean of 49.60 ml/kg/min and a final group mean of 51.91 ml/kg/min

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[9]Councilman, op. cit., pp. 25-36.

[10]Maxwell L. Howell, et al., "Intercollegiate Athletics and Maximal Oxygen Consumption" (Fitness Research Unit, University of Alberta, Edmonton, Alberta), pp. 1-38.

[11]Paul Brynteson, "Changes in Selected Bodily Responses of College Football Players following Their Competitive Season" (unpublished Master's thesis, Springfield College, 1968), pp. 1-83.

after 10 weeks of conditioning in 50 freshman male volunteers at South Dakota State University.[12]

The subjects studied in the present investigation appeared to be in better physical condition than the subjects studied by Howell and Swisher and compared favorably to the initial results in Brynteson's study. During the competitive season the subjects exhibited a higher maximal oxygen uptake than had been reported by Magel and Anderson (58.50 ml/kg/min) and Magel and Faulkner (54.70 ml/kg/min) for college swimmers.[13, 14] According to Cooper's Fitness Category of men under 30 years of age, the subjects were in "excellent" physical condition at the time of the initial test.[15]

The results obtained from the maximal oxygen uptake test in this investigation indicate no significant increase in cardiovascular condition. This coincides with the literature concerning athletic

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[12]Swisher, loc. cit.

[13]John R. Magel and Lange Andersen, "Pulmonary Diffusing Capacity and Cardiac Output in Young Trained Norwegian Swimmers and Untrained Subjects," Medicine and Science in Sports, 1:131-139, September, 1969.

[14]John R. Magel and John A. Faulkner, "Maximum Oxygen Uptakes of College Swimmers," Journal of Applied Physiology, 22:929-938, May, 1967.

[15]Kenneth H. Cooper, The New Aerobics, (New York: M. Evans and Company, Inc., 1970), pp. 28-29.

teams and contradicts literature concerning general populations.[16, 17, 18] The absence of significant improvement in the cardiovascular endurance of the swimmers in this investigation probably results from the swimmers' initial excellent condition and high maximal oxygen uptake attained through their participation in jogging and distance swimming prior to the swimming season.

The mean increase in maximal pulmonary ventilation of 7.37 liters per minute from Test I to Test V was not statistically significant in order to plot a regression curve. The results of the analysis of variance of maximal pulmonary ventilation was statistically significant indicating variability between the means. At the time of the initial test the subjects possessed a high maximal pulmonary ventilation mean of 162.06 liters per minute. Saltin and Astrand determined a high mean pulmonary ventilation during maximal exercise of 158.70 liters per minute for Swedish athletes.[19] Magel and Andersen reported a high mean maximal pulmonary ventilation of

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[16] Howell, et al., loc. cit.

[17] C. A. Knehr, D. B. Dill and W. Neufeld, "Training and Its Effects on Man at Rest and at Work," American Journal of Physiology, 136:148-156, March, 1942.

[18] S. Robinson and P. M. Harmon, "The Effect of Training and of Gelatin upon Certain Factors which Limit Muscular Work," American Journal of Physiology, 133:161-169, May, 1941.

[19] Bengt Saltin and P. O. Astrand, "Maximal Oxygen Uptake in Athletes," Journal of Applied Physiology, 23:353-358, September, 1967.

143.80 liters per minute for young trained Norwegian swimmers.[20] Maximal pulmonary ventilation of 162.06 liters per minute determined in the present study is considered very high and can be attributed to the subjects' excellent physical condition.[21] Kelly concludes that when oxygen is being consumed at maximum levels, pulmonary ventilation is highly related to maximal oxygen uptake.[22] The investigator's conclusion, based upon related literature and the present study, is that although mean differences in the subjects' physical condition show slight improvement, no statistically significant improvement was made because of the high maximal oxygen uptake and maximal pulmonary ventilation the subjects possessed before the competitive season began.

The lack of significance when polynomial regression and analysis of variance treatments were applied to ventilation equivalence for oxygen suggest that there were no significant differences between means and that a specific regression curve could not be plotted. Mean

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[20]Magel and Andersen, loc. cit.

[21]Saltin and Astrand, loc. cit.

[22]John M. Kelly, "The Relationship between Selected Measured of Pulmonary Function and Cardiovascular Fitness" (unpublished Doctor's dissertation, Springfield College, 1969), pp. 1-173.

ventilation equivalence for oxygen increased along with the mean maximal pulmonary ventilation because ventilation equivalence for oxygen is dependent upon maximal oxygen uptake and maximal pulmonary ventilation.[23] Because of the initially high maximal oxygen uptake and maximal pulmonary ventilation values, ventilation equivalence for oxygen did not significantly improve.

It is interesting to note that the performance times of many of the varsity swimmers in their speciality stroke were progressively improving throughout the season. Figures 2 and 3 show the performance times of two swimmers at each of the successive swimming meets during the season and in the investigator's opinion improving performance by the team throughout the season. Therefore, even though only one of the variables related to swimming showed a significant improvement trend throughout the season, performance times of the two swimmers did show a graphic improvement throughout the season. Apparently there are more factors related to the improvement of swimming performance than just those analyzed in this study.

The hypothesis of this investigation that no significant trend could be observed in body weight, percent body fat, forced expiratory volume for one second, forced vital capacity, endurance dips, vertical

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[23]Peter V. Karpovich, Physiology of Muscular Activity, (sixth edition, Philadelphia and London: W. B. Saunders Company, 1965), pp. 130-148.

Figure 2

Performance Times of B. E. in the 200 Yard Breaststroke

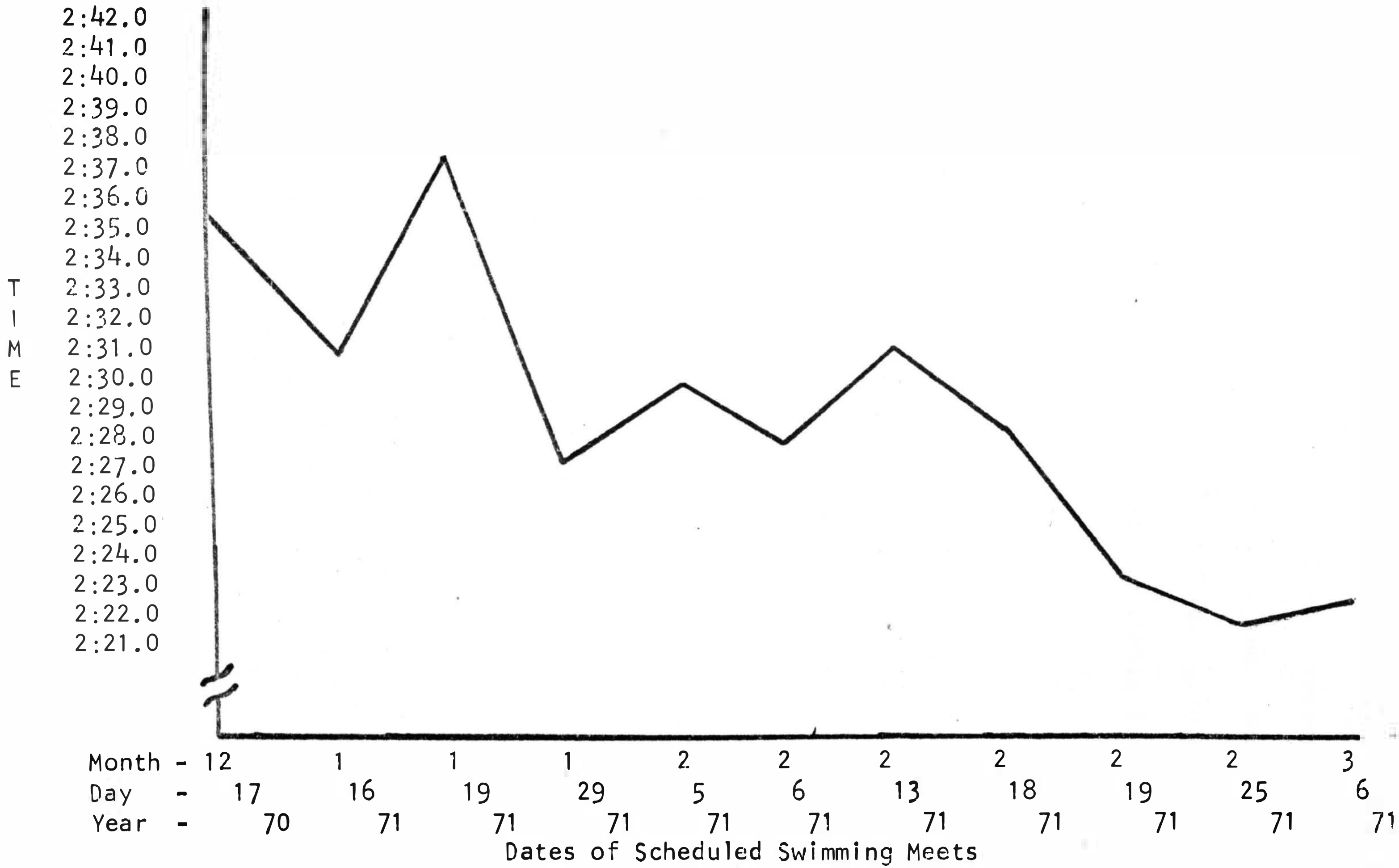

Figure 3

Performance Times of R. A. in the 200 Yard Butterfly power jump, maximal oxygen uptake, maximal pulmonary ventilation, and ventilation equivalence for oxygen throughout a season of competitive swimming and training cannot be totally accepted. The null hypothesis in regard to muscular endurance of the shoulder girdle as measured by endurance dips is rejected; the null hypothesis for the remaining eight parameters is retained as stated.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary of the Study

The purpose of this study was to determine the physiological changes of selected bodily responses of varsity swimmers throughout a season of competitive swimming and training.

The subjects were eight South Dakota State University varsity swim team members. All subjects were tested six times with approximately five weeks between tests. The study was completed over a twenty-five week period, the first test being administered on October 12, 1970, just prior to the beginning of organized practice, and the last test being administered on April 3, 1971, four weeks after the completion of competition. The physiological parameters that were measured were body weight, percent body fat, forced expiratory volume for one second, forced vital capacity, endurance dips, vertical power jump, maximal oxygen uptake, maximal pulmonary ventilation, and ventilation equivalence of oxygen.

Data were collected and recorded in such a manner that changes in the physiological parameters could be analyzed. Polynomial regression analysis was applied to the data to determine whether they fit a linear, quadratic, cubic, quartic or pentic equation. The polynominial regression statistic was applied only to the data on Test I, II, IV, and V. Tests III and VI were deleted from the polynomial regression statistics because they were not indicative of the season's training. Test III was taken immediately after Christmas vacation, during which no scheduled practices were held, and Test VI was taken three weeks after the completion of the regularly scheduled swimming season. Analysis of variance was a second statistical treatment applied to the data on all six tests to provide additional statistical information which could assist in the interpretation of results. The .05 level of confidence was accepted as the minimal level required in order to reject the null hypothesis.

The results of the polynomial regression statistics for all variables indicated that only endurance dips fit a specific regression curve. This curve was linear and in a positive direction.

The results of the analysis of variance for all variables indicated that endurance dips, percent body fat, forced expiratory volume for one second, forced vital capacity, and maximal pulmonary ventilation were significant. Analysis of variance revealed differences between means, but the polynomial regression failed to show a significant trend in all but one of the parameters: endurance dips.

Conclusions

Within the limitations of this investigation the following conclusions were drawn:

1. That the subjects were in excellent physical condition at the onset of the swimming season.

2. That the subjects did not show early gains or reach a point in the competitive swimming and training where improvement reached a plateau or hit a peak.

3. That there were some mid-season fluctuations, but overall there were few significant trends.

4. That the season of competitive swimming and training at South Dakota State University affected each investigated parameter differently. Only one parameter, however, the endurance dips, significantly increased in a positive linear direction throughout the competitive season.

Recommendations

The following recommendations are made for further study:

1. That a similar study be undertaken using a greater number of subjects.

2. That a similar study be undertaken over a longer period of time to determine the year-round changes and fluctuations in swimmers' physical condition.

3. That a similar study be completed where measures in addition to those used in this study are analyzed, such as red-blood cell count, hemoglobin, cholesterol level, maximum lactate tolerance, cardiac output, blood pressure, maximal oxygen debt, and other functional and dimensional measures.

4. That a similar study be undertaken using distance swimmers, middle distance swimmers, and sprinters and comparing the three groups on the various physiological parameters.

5. That studies similar to the present investigation be undertaken to analyze the effects of various athletic seasons on the participants.

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APPENDIX A

SAMPLE TRAINING ROUTINES DURING THE SWIMMING SEASON

At the start of the swimming season, the swimming team workouts consisted mostly of overdistance and Fartlek training. During this phase the swimmers averaged 2,500 to 3,000 yards a night. The latter part of November and all of December up to Christmas break, consisted of fast and slow interval training with some overdistance; during this phase the swimmers averaged 2,000 to 2,500 yards a night.

After Christmas vacation, the swimming team began over-distance and some Fartlek training. This routine lasted the first week and a half of January; the distance covered averaged 2,500 to 3,000 yards a night. During the latter half of January and into February, the swimmers practice consisted of fast and slow interval training with very little overdistance. The emphasis was placed on more quality rather than on more quantity. Times for each repeat swim were lowered to be faster, up to 100 yards. The months of February and early March consisted of fast interval and repetition training; complete rest periods with emphasis being placed on speed: high quality, less quantity. During the following phases, workouts were organized to (1) break monotony, (2) increase quantity or endurance, and (3) increase speed or quality of swimming.

October-December. The following are three sample workouts used during these three months:

1. Flexibility exercises

   Fartlek kicking (400 yards)

   Fartlek pulling (800 yards)

   Fartlek swimming (1,200 yards)

   Two 25-yard underwater swims

2. Flexibility exercises

   Overdistance kicking (400 yards)

   Overdistance pulling (800 yards)

   Overdistance swimming (1,200 yards)

   Four 25-yard underwater swims

3. Flexibility exercises

   200-yard Individual Medley warm-up

   Five 50-yard kicks (47 sec. or better)

   Ten 50-yard pulls (36 sec. or better)

   Five 100-yard swims (1:10 or better)

   Five 75-yard swims (55 sec. or better)

   Five 50-yard swims (33 sec. or better)

   Five 25-yard swims (14.5 sec. or better)

January. The following are three sample workouts used during this month:

1. Flexibility exercises

   200-yard Individual Medley warm-up

Kicking (200 yards)

Pulling (200 yards)

Swimming (1,500 yards)

Ten 25-yard swims (14.5 sec. or better)

Four 25-yard underwaters

2. Flexibility exercises

Ten 25-yard kicks (25 sec. or better)	Incomplete rest
Ten 25-yard pulls (15 sec. or better)	Incomplete rest
Ten 50-yard pulls (37 sec. or better)	Incomplete rest
Three 75-yard swims (55 sec. or better)	Incomplete rest
Three 100-yard swims (1:15 or better)	Incomplete rest
Twenty 25-yard swims (14 sec. or better)	Incomplete rest

Four 25-yard no breathers (swimming 25 yards without breathing)

3. Flexibility exercises

Ten 25-yard kicks (20 sec. or better)	Incomplete rest
Ten 50-yard pulls (35 sec. or better)	incomplete rest
One 75-yard swim (60 sec. or better)	Incomplete rest
One 75-yard swim (55 sec. or better)	Incomplete rest
One 75-yard swim (50 sec. or better)	Incomplete rest
One 75-yard swim (48 sec. or better)	Incomplete rest
One 75-yard swim (50 sec. or better)	Incomplete rest
One 75-yard swim (55 sec. or better)	Incomplete rest

One 75-yard swim	(60 sec. or better)	Incomplete rest
Three 100-yard swims	(1:08 or better)	Incomplete rest
Six 25-yard swims	(13.5 sec. or better)	

February and March. The following are three sample workouts used during these two months:

1. Flexibility exercise

200-yard Individual Medley warm-up

Ten 25-yard kicks	(18 sec. or better)	Complete rest
Fifteen 25-yard pulls	(14.5 sec. or better)	Complete rest
Twenty 25-yard swims	(13.5 sec. or better)	Complete rest
Five 75-yard swims	(50 sec. or better)	Complete rest
Five 100-yard swims	(1:05 or better)	Complete rest

Cool down (swim easy 150 to 200 yards)

2. Flexibility exercises

200-yard Individual Medley warm-up

Five 25-yard kicks	(18 sec. or better)	Complete rest
Five 50-yard pulls	(35 sec. or better)	Complete rest
Five 75-yard swims	(45 sec. or better)	Complete rest
Five 50-yard swims	(28 sec. or better)	Complete rest
Ten 25-yard swims	(13 sec. or better)	Complete rest

Cool down (swim easy 150 to 200 yards)

3. Flexibility exercises

400-yard Individual Medley warm-up

Two 25-yard kicks	(17 sec. or better)	Complete rest
Two 50-yard pulls	(34 sec. or better)	Complete rest
Five 75-yard swims	(42 sec. or better)	Complete rest
Five 50-yard swims	(26 sec. or better)	Complete rest
Ten 25-yard swims	(12 sec. or better)	Complete rest

Cool down (swim easy 150 to 200 yards)

APPENDIX B

TABLE VI

RAW DATA FOR WEIGHT

Subjects	Test I	Test II	Test III	Test IV	Test V	Test VI
R.A.	157	158	158	155	158	161
J.A.	185	179	182	177	177	175
B.E.	161	163	167	166	167	166
S.G.	131	130	135	138	136	139
J.M.	178	174	178	178	176	176
R.M.	149	152	150	153	153	154
K.S.	195	190	195	193	193	195
R.T.	163	161	163	160	163	163
Mean	164.87	163.28	166.06	164.93	165.31	166.15
S.D.	20.63	18.35	18.85	17.42	17.16	16.84

TABLE VII

RAW DATA FOR $FEV_{1.0}$

Subjects	Test I	Test II	Test III	Test IV	Test V	Test VI
R.A.	4256.29	4019.46	4843.44	4391.31	4732.28	4275.40
J.A.	4033.73	3549.21	4022.44	4199.88	4037.23	4140.75
B.E.	4086.05	4115.44	4708.71	4819.01	4894.96	4954.11
S.G.	2963.51	2776.81	3246.38	3261.00	3223.86	3356.96
J.M.	4426.30	3756.25	4259.06	4022.44	4037.23	4244.26
R.M.	3894.71	3514.41	3833.15	3678.81	4111.17	3844.98
K.S.	4992.74	4336.72	4861.08	4769.15	4968.90	5112.85
R.T.	5373.24	4917.73	5132.91	5377.31	5318.87	5382.98
Mean	4253.32	3873.25	4363.39	4314.86	4415.56	4414.03
S.D.	726.96	633.44	637.56	677.08	682.96	684.81

TABLE VIII

RAW DATA FOR PERCENT BODY FAT

Subjects	Test I	Test II	Test III	Test IV	Test V	Test VI
R.A.	12.8	13.0	9.2	10.3	11.8	10.8
J.A.	15.8	19.2	16.8	17.3	16.1	15.9
B.E.	8.6	8.5	8.2	7.8	7.8	8.1
S.G.	13.8	13.7	13.1	15.3	14.7	14.9
J.M.	13.8	16.7	12.2	13.3	13.4	12.5
R.M.	5.8	9.7	8.4	9.4	9.7	9.1
K.S.	13.1	11.7	10.4	11.0	9.5	10.7
R.T.	8.2	9.7	4.9	4.2	7.4	6.6
Mean	11.48	12.77	10.46	11.07	11.31	11.07
S.D.	3.48	3.70	3.58	4.19	3.23	3.22

TABLE IX

RAW DATA FOR FVC

Subjects	Test I	Test II	Test III	Test IV	Test V	Test VI
R.A.	4353.01	4244.10	5140.59	4478.56	4850.59	4495.78
J.A.	4590.87	3667.52	4791.44	4791.44	4717.50	4880.17
B.E.	4175.86	4278.87	4898.81	5127.54	5323.82	5501.28
S.G.	2963.51	2776.81	3246.38	3261.00	3253.45	3401.33
J.M.	4867.42	3859.77	4761.86	4673.13	4702.71	4835.81
R.M.	4052.29	3559.09	4401.73	4551.26	4702.71	4554.83
K.S.	5350.96	4545.40	5417.92	5333.73	5471.71	5480.15
R.T.	5732.52	4917.73	5132.91	5612.38	5408.01	5486.50
Mean	4510.80	3981.16	4723.95	4728.63	4803.81	4829.48
S.D.	851.34	664.93	670.39	713.26	708.50	710.67

TABLE X

RAW DATA FOR ENDURANCE DIPS

Subjects	Test I	Test II	Test III	Test IV	Test V	Test VI
R.A.	11	15	19	21	23	23
J.A.	16	21	23	26	27	29
B.E.	15	19	23	26	28	30
S.G.	10	11	17	19	18	21
J.M.	11	15	16	25	20	23
R.M.	24	25	28	35	39	41
K.S.	29	30	32	34	30	37
R.T.	13	16	12	20	25	25
Mean	16.12	19.00	21.25	25.75	26.25	28.60
S.D.	6.85	6.16	6.58	6.04	6.54	7.17

TABLE XI

RAW DATA FOR VERTICAL POWER JUMP

Subjects	Test I	Test II	Test III	Test IV	Test V	Test VI
R.A.	150.45	151.42	151.41	140.20	151.42	150.93
J.A.	224.15	200.81	200.81	199.12	184.37	196.87
B.E.	191.19	200.35	194.83	214.40	215.70	214.41
S.G.	131.00	129.50	141.50	141.50	141.60	144.79
J.M.	155.53	137.75	155.75	155.75	161.33	161.33
R.M.	158.31	177.62	150.00	153.00	140.25	159.89
K.S.	227.50	233.54	211.25	217.12	232.60	240.61
R.T.	189.87	177.77	177.77	153.33	163.00	169.79
Mean	178.50	176.09	168.85	171.79	173.78	179.82
S.D.	35.36	35.36	22.21	32.69	13.42	33.98

TABLE XII

RAW DATA FOR MAXIMAL $\dot{V}_{O_2}$

Subjects	Test I	Test II	Test III	Test IV	Test V	Test VI
R.A.	56.60	57.87	61.40	59.62	58.00	60.73
J.A.	53.19	51.04	53.36	63.63	55.89	54.58
B.E.	57.34	62.25	60.16	69.66	61.42	63.61
S.G.	59.94	68.16	64.59	62.62	63.37	63.85
J.M.	63.50	59.83	58.81	63.70	65.33	62.20
R.M.	68.79	61.25	62.73	60.90	60.50	65.78
K.S.	57.29	56.69	54.86	62.60	53.41	52.62
R.T.	66.40	69.28	49.51	77.94	74.55	71.99
Mean	60.38	60.79	58.17	65.08	61.55	61.92
S.D.	5.36	5.97	5.15	5.97	6.53	6.15

TABLE XIII

RAW DATA FOR MAXIMAL $\dot{V}_E$

Subjects	Test I	Test II	Test III	Test IV	Test V	Test VI
R.A.	179.05	151.56	190.35	169.08	171.75	201.37
J.A.	172.64	153.04	154.74	190.14	162.94	166.53
B.E.	133.43	153.23	154.72	185.08	146.85	155.33
S.G.	145.45	130.64	163.83	142.86	157.32	163.58
J.M.	169.00	138.94	178.42	178.84	171.02	161.05
R.M.	168.64	183.08	145.86	160.46	171.23	196.12
K.S.	172.99	161.64	165.52	190.44	187.71	196.12
R.T.	155.31	181.28	141.85	206.83	186.65	190.44
Mean	162.06	156.71	161.91	170.46	169.43	178.82
S.D.	15.82	18.39	16.31	20.02	13.84	18.87

TABLE XIV

RAW DATA FOR $\dot{V}E_{O_2}$

Subjects	Test I	Test II	Test III	Test IV	Test V	Test VI
R.A.	2.85	2.99	3.57	3.32	3.37	3.63
J.A.	3.24	3.01	2.78	3.03	2.95	2.77
B.E.	2.62	2.72	2.80	2.40	2.58	2.59
S.G.	2.74	2.65	3.43	2.99	3.27	3.33
J.M.	2.72	2.38	3.12	2.81	2.68	2.59
R.M.	3.04	2.94	2.83	2.34	3.46	3.49
K.S.	2.85	2.69	2.36	2.90	3.27	3.42
R.T.	2.62	2.93	3.22	2.92	2.77	2.40
Mean	2.83	2.78	3.01	2.84	3.04	3.03
S.D.	.214	.218	.396	.326	.341	.486

APPENDIX C

TABLE XV

SOUTH DAKOTA STATE UNIVERSITY 1970-71 SWIMMING SCHEDULE

School	Site	Date
Kearney State College Kearney, Nebraska	Brookings, South Dakota	12/17/70
Concordia College Seward, Nebraska	Seward, Nebraska	1/16/71
Northwest Missouri State College Maryville, Missouri	Seward, Nebraska	1/16/71
University of South Dakota Vermillion, South Dakota	Vermillion, South Dakota	1/19/71
Southwest Minnesota State College Marshall, Minnesota	Marshall, Minnesota	1/29/71
University of North Dakota Grand Forks, North Dakota	Grand Forks, North Dakota	2/ 5/71
Southwest Minnesota State College Marshall, Minnesota	Grand Forks, North Dakota	2/ 5/71
North Dakota State University Fargo, North Dakota	Fargo, North Dakota	2/ 6/71
Chadron State College Chadron, Nebraska	Brookings, South Dakota	2/13/71
Wayne State College Wayne, Nebraska	Brookings, South Dakota	2/18/71
Mankato State College Mankato, Minnesota	Mankato, Minnesota	2/19/71
University of South Dakota Vermillion, South Dakota	Brookings, South Dakota	2/25/71
NCIAC Meet	Mankato, Minnesota	3/4,5,6/71